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LARGE AREA GLASS COATING

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equipment is very costly, especially the pane cleaning, the air-conditioning of the room with the dip coaters and the furnace required to finally fire the layers. Moreover, even the largest plants only have a production capacity of about 50,000 m²/a, i.e. the process is suitable only for niche flat glass products made in small quantities.

However, it is another advantage that bent panes, especially cylindrically bent panes, can also be coated, at no extra cost. It is in the nature of the dipping technique that both sides of a pane are coated. This is advantageous for the production of anti-reflective coatings, but it can be a disadvantage in other applications. However, it is possible with the dipping technique to coat the panes on one side only, by sticking two panes together before the coating process and separating them afterwards.

It should be noted that the sol-gel coating process is increasingly used to coat substrates other than flat glass panes.

Other sol-gel coating techniques

As mentioned above, sol-gel films can be applied by other techniques as well. It has been suggested that the coating solution could be rolled on, similar to the application of paint, or drained off over obliquely positioned panes, i.e. by the flow technique. These are typical thick film application techniques which, of course, are suitable only for relatively thick layers with a limited layer eveness. This might be adequate for the production of, for example, hydrophobic layers on flat glass (see Chapter 5.5.2). The chemical processes and other equipment, such as the pane cleaning stage or the firing furnace are the same as for the dipping technique.

4.4 Plasma-assisted CVD

Plasma-assisted CVD (PACVD), also called plasma-enhanced CVD (PECVD) is closely related to the chemical vapour deposition (CVD) described in Chapter 4.3.2.*3*. With both processes almost the same types of layers can be coated on the basis of the same coating materials. However, PACVD differs from conventional CVD in that the chemical reactions are not initiated by heat, but by electromagnetic energy supplied by a gas discharge process, i.e. a plasma. In this way, chemical *and* physical processes concur during a PACVD coating, for which reason this process can be classified somewhere in between physical and chemical

types of coating processes. It should be noted that the energy required to form the coating can also be added in the form of light energy. This process is called light-assisted CVD (LACVD). Until now, LACVD has not been utilised for flat glass coating.

PACVD does not yet play a large role among the flat glass coating processes used on a commercial scale. Today, only thin film amorphous silicon solar cells are made by this process (see Chapter 7). It is conceivable though, that it will be used more often in the future for flat glass coating, in order to achieve new functions, e.g. to produce flat glass surfaces which are easier to clean or which become contaminated less quickly (see Chapter 5.5.2). For this reason, the working principle of this coating technology will be explained in the following paragraphs, without too much emphasis on details.

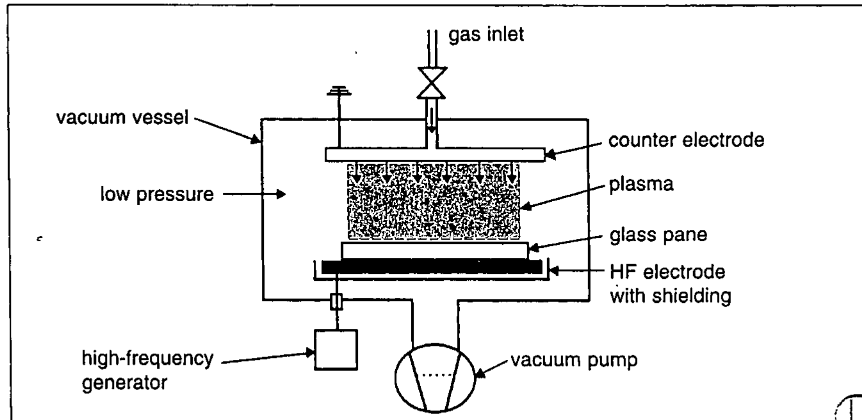

Figure 4.4.1:
Basic layout of a PACVD plant

Figure 4.4.1 shows the basic layout of a PACVD plant. The installation is similar to the one used for sputtering (see Chapters 4.2.1, Figure 4.2.1.*3.1*). The basis of the coating process is the plasma of the working gas, which is also called the precursor, as in the conventional CVD process. The plasma is ignited with high-frequency (HF) electromagnetic energy. The frequency allowed for industrial processes is 13.56 MHz. Generally, the process can also be run with a direct current plasma. However, using high frequency allows electrically insulating layers or layers on electrically insulating substrates (such as flat glass) to be deposited.

In contrast to the sputtering process, plasma does not have the function to erose particles of the coating material

from a cathode by means of ion bombardment (see Chapter 4.2.1.*2*), but instead decomposes the molecules of the precursor, splitting them up into chemical groups and/or transforming them into an electrically charged state. These plasma products, which are chemically highly reactive, are deposited on the substrate surface at low temperatures and under the influence of certain chemical reactions. Because the layers are formed by chemical reactions, PACVD can also be considered as a special form of the CVD process. Of course, the plasma itself also affects layer formation, as in the case of sputtering processes (see Figure 4.2.1.*3.2*).

The main advantage of PACVD is that, compared to the CVD processes which use thermal energy, a high decomposition rate of the coating gas is displayed, thus allowing for higher deposition rates at lower temperatures. For example, the deposition rate of a silicon layer based on hydrosilicon as the precursor, with ordinary CVD at 650°C is only one tenth of the rate achieved using PACVD. Therefore, the use of PACVD is particularly advisable when high deposition rates at cold substrates (approximately 20°C) are to be achieved with CVD processes.

Typical chemical reactions performed with PACVD processes are, for example, the above-mentioned deposition of silicon layers on the basis of hydrosilicon, according to the reaction:

$$(SiH_4)_{gaseous} \xrightarrow{HF\ energy} (Si)_{solid} + 2(H_2)_{gaseous}\uparrow$$

or the deposition of a carbon layer on the basis of methane, according to the reaction

$$(CH_4)_{gaseous} \xrightarrow{HF\ energy} (C)_{solid} + 2(H_2)_{gaseous}\uparrow$$

where the indices "gaseous" and "solid" describe the state of aggregation of the coating material and/or that of the reaction products. It should be noted that the reactions are actually somewhat more complicated than is shown here. In the gas discharge zone, a number of chemical groups, e.g. CH_2 or SiH_3, or molecules arise as intermediate products, which are only reduced to carbon or silicon during further reaction steps, depending on the procedure employed. By controlling the process in a certain way, it is also possible to form layers which consist of or contain reaction products of the precursor which arise in the plasma. If the layers are interlinked like plastics, the process is also known as *plasma polymerisation*. Moreover, by using additives in the precursor, the layers can be doped, resulting in quite significant alterations of layer properties (see Chapter 5.5.2.*1*).

Today, PACVD is used predominantly to coat flat glass with

carbon- or silicon-containing layers with various chemical compositions. Using this coating technique, oxides, nitrides, carbides and oxinitrides of the elements aluminium, boron, germanium and titanium can also be deposited. The process becomes particularly interesting when large-sized flat glass panes have to be coated and conventional CVD is not feasible, e.g. for the deposition of hydrophobic silicon-containing layers for easy-to-clean glass surfaces or for surfaces which do not quickly become contaminated, and for the deposition of amorphous silicon layers used for the transformation of solar energy into electrical energy (see Chap-ter 7). However, for both applications it has not yet been discovered, whether the PACVD technique forms the optimum technical solution. Regarding the plant and technology design, it is possible to coat flat glass panes of up to approximately 1 m^2 today. It is therefore only fair to say that PACVD is presently only in the initial stage of development.

In a special arrangement, PACVD is already successfully used, particularly by the German group *Schott Glaswerke* Mainz, to coat smaller glass surfaces, e.g. to make easy-to-clean spectacle lenses, chemically highly-inert ampoules and bottles for the pharmaceutical industry or infrared-reflecting interference filters — a special type of dielectric mirrors (see Chapter 5.4.2) required in the manufacturing of energy-saving lamps. The deposited layers used here are of various types. Spectacle lenses with a hydrophobic surface are made from modified silicon oxide, using precursors on the basis of hexamethyl disilane (HMDS). The highly inert surfaces for pharmaceutical ampoules and bottles and the infrared reflection for energy-saving lamps are achieved with layers of oxides of silicon, titanium and tantalum or with layer systems which consist of these oxides.